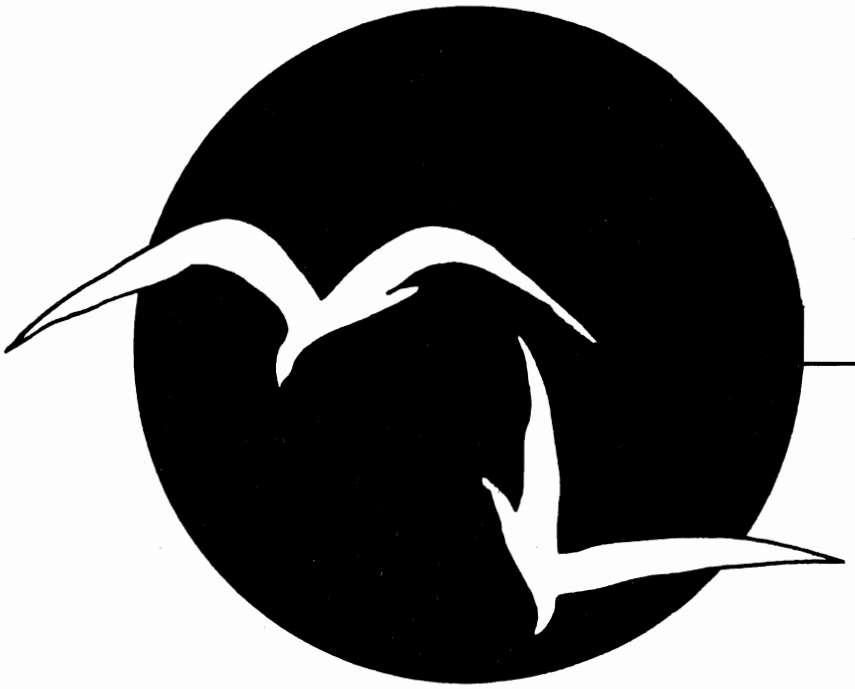

Moss Landing Marine Laboratories

Technical Publication 72-7

BIOLOGICAL STUDIES

Annual Report, Part 5, September 1972

by

Moss Landing Marine Laboratories Sea Grant Staff

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Robert E. Arnal, Sea Grant Project Coordinator

Moss Landing Marine Laboratories
of the
California State University
at
Fresno, Hayward, Sacramento, San Francisco, and San Jose

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SURVEY OF THE BENTHIC INFAUNA OF NORTHERN MONTEREY BAY, CALIFORNIA AUGUST 1971 TO JUNE 1972

INTRODUCTION

Currently, the communities surrounding Monterey Bay are using bay waters for disposal of domestic and industrial waste. Until economically feasible methods for reclamation are established, the waters of the bay will continue to be utilized as the most practical discharge site. Rapid growth of these coastal communities dictates that volumes of waste from existing outfalls will also increase rapidly and/or new outfalls will be established.

In order for the local communities and the regional State Water Quality Control Board to make intelligent judgements about the proper balance between the requirements of waste disposal and those of maintaining environmental quality, much more information is needed about natural environmental characteristics. This basic information was almost totally lacking for Monterey Bay.

Previous ecological surveys in relation to the problems of waste disposal in the marine environment have shown that benthic infaunal communities are susceptible to various degrees of pollution. In addition, their relative stability as opposed to plankton associations makes them convenient communities to monitor over an extended period of time. Therefore, a better understanding of these communities in Monterey Bay would be very useful to those people making decisions

about environmental quality. Since so little is known, it is necessary to start at a basic level.

In July, 1970, Moss Landing Marine Laboratories initiated a limited qualitative study of the benthos at several shallow water stations in the bay to gather some baseline data. Based on the experience and data gathered by this investigation, a more extensive study was initiated in August, 1971. The main objective of this study is to obtain quantitative information of the community composition of the shallow water benthic infauna of northern Monterey Bay and to evaluate its natural variation in time and space. Permanent stations were chosen which represent the major depth and sediment regimes of the northern Bay. In addition, some stations were placed in areas which are likely to be affected by waste disposal in the near future. Wherever possible, the location of stations was chosen to coincide with sampling stations used by the other participants in the Sea Grant program in gathering data on hydrography, phytoplankton biomass and productivity. This ensures that a maximum amount of information is available for analyzing the data for temporal and spatial differences in benthic infaunal communities.

In addition, sampling procedures used are similar, though refined, to those employed by Welton Lee of Hopkins Marine Station and Eugene Haderlie of United States Naval Postgraduate School in their study of the benthic infauna of southern Monterey Bay. This will permit comparisons of data from the two halves of the bay.

Initially the study was supported solely by a grant from the Office of Sea Grant Programs, U.S. Department of Commerce. In September, 1971,

additional support to expand and improve this work was received from the Association of Monterey Bay Area Governments (AMBAG).

SCIENTIFIC PERSONNEL

Patrick Clark - Sea Grant Teaching Assistant

Alfred Hodgson - Biological technician

Gary McDonald - Graduate student

James Nybakken - Associate professor

Michael Panietz - Graduate student

David Shonman - Graduate student

Peter Slattery - Graduate assistant

Barry Turner - Sea Grant Teaching Assistant

In addition to the above personnel, students employed as hourly help and students enrolled in the undergraduate research class "Environmental Research Participation" have greatly aided in shipboard sampling and laboratory sorting of samples.

ACKNOWLEDGEMENTS

Special thanks are due to Dr. Olga Hartman, Dr. Christian Fauchald, Dr. John Garth, and Dr. Robert Given of the Allan Hancock Foundation, University of Southern California; Dr. Meredith Jones, and Dr. Louis Kornicker of the United States National Museum; Dr. Allyn Smith, James Carlton, and Ernest Iverson of the California Academy of Sciences; Dr. Diana Laubitz of the National Museum of Canada; Dr. Charlotte Holmquist of Naturhistoriska Riksmusseet, Sweden; and

Jim Sutton of Hopkins Marine Station for generously donating their time to check numerous identifications of organisms. Without their assistance, a project such as this would not have been possible.

METHODS AND MATERIALS

A. Choice of Stations

Sampling for the Sea Grant Program of the Moss Landing Marine Laboratories was initiated in August, 1971 at ten permanent stations in northern Monterey Bay. The positions of these stations are spread out over a large area of the bay north of the Monterey Submarine Canyon and cover a wide range of depth and sediment type. Areas with rocky substratum are unsuitable for sampling with grabs and were avoided. Also avoided were stations located on the steep slopes of the canyon due to the difficulty of maintaining a constant depth with each replicate sampling.

These ten permanent stations are being used also for the AMBAG project. Two stations were added at the request of AMBAG. However, the one new station located outside of the bay had to be eliminated due to financial cutbacks, leaving eleven permanent stations. A list of the eleven permanent stations and their positions is given in the progress report: First half of second year of operation - July 1971 - February 1972 Moss Landing Marine Laboratories Sea Grant Program.

B. Sampling Procedures

The stations are located by the use of loran and radar with an accuracy to .1 of a nautical mile. The ship is not anchored at the stations and the amount of drift must be constantly watched and recorded. During sampling, the navigator takes continuous fathometer readings and frequent position readings. If the depth changes more than a few

meters or if the ship drifts more than .3 nautical miles, the ship sails back to the correct position.

Sampling is being done with the highly efficient Smith-McIntyre grab (McIntyre, 1954) which has a sampling area of .1 m^2. Initially, eight replicates for faunal analysis were taken at each station. This was the number used by Lee and Haderlie for their benthic study in southern Monterey Bay. The number of replicates was later dropped to six due to time and financial limitations. However, previous work in 18 meters near Moss Landing shows that this number is adequate for sampling the majority of the species of polychaeta which is the dominant benthic phylum.

Seven grab samples are taken at each station. Three subsamples are taken from the fourth sample and the temperature of the sediment is measured. The remainder of the sediment is discarded. The subsamples are for sediment particle size analysis, organic content and heavy metal determination, as well as DDT and nutrient uptake analysis. The subsampling is made through a door on top of the grab by pushing glass jars into the surface of the sediment to a depth of about five centimeters, thus taking a core of the sediments.

For each of the six replicate samples used for faunal analysis, the depth of the sediment contained in the bucket is measured through the door on the top of the grab. This measurement is used to determine the volume of sediment. The contents of the grab are then emptied into a styrofoam ice chest for storage until they can be sieved.

Starting with the May sampling period we initiated more intensive sampling at station 1105 off the Pajaro River. The number of replicates

for faunal analysis was increased from six to ten, and we are saving and identifying all of the organisms found on the 0.5 mm screen in addition to those trapped on the 1.0 mm screen. Perhaps the additional time required to do this will pay off in terms of increased ability to detect seasonal variations.

Sieving is done on board ship. The sample is washed from the ice chest onto the screen with a hose. Water used in this operation is pumped from the bay and passes through a filter to remove all planktonic organisms larger than the mesh size used for sieving. A low velocity of water is maintained in order to prevent unnecessary damage to the specimens.

Larger polychaetes are picked from the screen while the sample is being sieved. They are relaxed in propolyene phenoxitol diluted 1:99 with sea water, bottled, and preserved in 10% formalin buffered to neutral pH with hexamethylenetetramine. Ophiuroids are also picked from the screen during the sieving process, killed by placing in distilled water, bottled separately, and preserved in 10% buffered formalin. All of the material left on the 1 mm screen is checked for large polychaetes. If any are found, they are also placed in the bottle. Organisms are then relaxed with magnesium chloride and stained with Rose Bengal. After allowing the sample to stand for about an hour, it is preserved in 10% buffered formalin.

C. Laboratory Methods

The preserved samples are brought back to the laboratory for sorting. Small portions from the bottles containing the 1 mm mesh

screenings are put in glass petri dishes with freshwater, and the organisms are picked out under a dissecting microscope with a pair of fine forceps. The Rose Bengal stains the organisms pink so that they are more readily separated from the remaining sediment and debris. The organisms are placed into six major groups: Polychaeta, Bivalvia, other Mollusca, Crustacea, Echinodermata, and miscellaneous phyla. These are bottled separately, labeled and preserved in 70% ethanol. This initial rough sorting is being done by several part-time employees.

The bottles of Polychaeta, together with the bottles of larger Polychaeta separated on board ship, are further sorted to families. Identifications to the lowest possible taxa are then made by technicians and qualified graduate students and the individuals in each of these taxonomic groups are enumerated. The other major groups (Bivalvia, other Mollusca, Crustacea, Echinodermata, and other phyla) are sorted directly to the lowest taxa.

RESULTS

This report omits the data on the identifications of the organisms and their numbers per replicate at each station in time. This omission has been made because the identifications have not been entirely completed and in some cases are only tentative. The complete data will be presented with the final report, which will be compiled upon completion of the project in June, 1973.

Table 1 lists the sampling dates, depth, volume of sediment in each replicate sample, and the temperature of the sediment at the eleven permanent stations for the first year of sampling.

At this time, each of the eleven stations has been occupied four times and 276 individual samples have been collected. Almost all of the organisms have been identified and counted from these four sampling periods. Some remaining Echinodermata and individuals of poorly represented phyla have not yet been identified. Also, some Polychaeta, Gastropoda, and Crustacea still have to be checked by an expert systematist before their names can be presented with confidence.

Data on the pesticide, heavy metal, organic content and particle size analysis of the sediment at the eleven stations for the year is also almost complete, but is omitted until it can be presented in its entirety.

During the coming year, sampling will continue at all stations. Samples will be taken in August, November, and February so that we will have almost two full years of data from which to evaluate natural spatial and temporal variability.

To date, the data has not been extensively analyzed. This phase of the project will begin after the data for the first year of sampling has been completely gathered. The spatial distribution of the bivalve molluscs collected from the first sampling period was analyzed by Patrick Clark. This analysis is presented in the attached paper entitled "The bivalve species present and an analysis of their spatial distribution in the northern sector of Monterey Bay" (P. Clark, 1971).

REFERENCE

McIntyre, A.D. 1954. A spring-loaded bottom sampler. J. Mar. Biol. Ass. U. K., 33: 257-264

TABLE 1

Sampling dates, depth, volume of sediment in each replicate sample, and temperature of the sediment at the benthic stations in northern Monterey Bay.

Date	Depth (m)	Number of replicate samples	Volume of sediment in each replicate (1) 1	2	3	4	5	6	7	8	9	10	Temperature of sediment (°C)
Station 1105													
21 Aug 1971	11	8	1	3	3	2	3	3	2	3			----
10 Nov 1971	16	6	5	5	4	4	3	3					----
2 Feb 1972	20	6	7	7	6	5	7	5					10.0
3 May 1972	19	10	6	6	7	5	6	6	5	6	6	7	10.5
Station 1154													
20 Aug 1971	13	8	3	5	3	5	1	2	2	2			----
10 Nov 1971	12	6	4	3	3	3	4	4					----
2 Feb 1972	17	6	7	5	5	4	4	5					10.1
3 May 1972	16	6	6	4	5	4	9	7					10.2
Station 1159													
20 Aug 1971	16.5	8	1	5	2	3	3	5	5	3			----
10 Nov 1971	12	6	6	4	7	7	5	5					----
2 Feb 1972	17	6	6	6	6	8	7	7					10.5
3 May 1972	18	6	11	9	10	9	9	6					10.0

TABLE 1 (Cont'd.)

Date	Depth (m)	Number of replicate samples	Volume of sediment in each replicate (l) 1	2	3	4	5	6	7	8	9	10	Temperature of sediment (°C)
Station 1158													
20 Aug 1971	26	8	5	4	5	4	4	3	3	4			----
10 Nov 1971	26	6	2	3	6	7	6	6					----
2 Feb 1972	17	6	7	6	5	5	6	4					10.5
3 May 1972	29	6	8	8	7	6	6	5					9.8
Station 1156													
21 Aug 1971	38	8	5	5	5	5	5	6	5	5			----
10 Nov 1971	34	6	7	9	11	12	8	6					----
2 Feb 1972	40	6	8	8	7	5	7	7					10.6
3 May 1972	37	6	11	8	9	7	9	9					10.8
Station 1175													
21 Aug 1971	38	8	8	9	7	8	7	8	7	6			----
10 Nov 1971	34	6	9	6	7	8	6	9					----
3 Feb 1972	35	6	6	5	6	7	5	7					10.2
10 May 1972	38	6	9	9	7	8	7	9					10.2

TABLE 1 (Cont'd.)

Date	Depth (m)	Number of replicate samples	Volume of sediment in each replicate (l) 1	2	3	4	5	6	7	8	9	10	Temperature of sediment (°C)
Station 1153													
13 Oct 1971	14	6	2	4	2	2	4	2					----
24 Nov 1971	14	6	4	5	8	3	3	4					11.8
3 Feb 1972	15	6	6	7	8	7	7	5					10.6
10 May 1972	16	6	4	4	5	5	4	5					11.0
Station 1152													
20 Aug 1971	27	8	5	6	8	5	7	6	6	5			----
24 Nov 1971	37	6	6	6	6	7	7	7					11.3
3 Feb 1972	38	6	7	10	9	8	8	11					10.6
10 May 1972	38	6	11	11	9	9	10	9					9.8
Station 1176													
13 Oct 1971	62	6	10	8	6	10	9	8					----
24 Nov 1971	62	6	9	10	8	8	10	9					11.2
3 Feb 1972	64	6	12	15	14	12	13	13					10.5
10 May 1972	61	6	11	11	10	9	10	10					10.0

TABLE 1 (Cont'd.)

Date	Depth (m)	Number of replicate samples	Volume of sediment in each replicate (l) 1	2	3	4	5	6	7	8	9	10	Temperature of sediment (°C)
Station 1177													
21 Aug 1971	35	8	4	2	3	4	2	4	4	3			----
24 Nov 1971	31	6	3	4	4	4	4	4					11.8
3 Feb 1972	35	6	4	6	4	5	4	4					10.5
10 May 1972	37	6	6	6	6	7	5	6					10.0
Station 1155													
Aug 1971													
24 Nov 1971	67	6	12	11	13	12	12	12					10.5
2 Feb 1972	65	6	14	13	13	13	11	13					10.4
3 May 1972	62	6	13	13	13	13	9	13					9.6

THE BIVALVE SPECIES PRESENT AND AN ANALYSIS OF THEIR SPATIAL DISTRIBUTION IN THE NORTHERN SECTOR OF MONTEREY BAY

ABSTRACT

The objectives of this paper are: 1) to make a list of the bivalve species sampled and to obtain an idea of the relative abundance of each species for the northern sector of Monterey Bay; and 2) to obtain an idea of the spatial distribution of the bivalve populations of the northern sector of Monterey Bay. The Kruskal-Wallace 1-way analysis of variance and Fager's determination of recurrent groups (Fager, 1957) were used to analyze the bivalve data obtained from the three Sea Grant-AMBAG cruises. It was found that there are four recurrent groups that occur in the northern sector of Monterey Bay and that these groups select certain depths as their habitat. It was found that there is not a significant difference in diversity with depth but that there is a highly significant difference in diversity among stations. It is suggested that the significant difference among stations is due to clumped populations at the sample stations.

INTRODUCTION

The bivalves of Monterey Bay have been sampled and identified by a number of people (Smith and Gordon, 1948; Keen and Frizzell, 1953: Fitch, 1953). The abundance of bivalve species of Monterey Bay has been reported, in a rather qualitative manner, by Smith and Gordon (1948) using a scale from rare to common. The objectives of this paper are: 1) to make a list of the bivalve species sampled and to obtain an idea of the relative abundance of each species in the northern sector of Monterey Bay; and 2) to obtain an idea of the spatial distribution of the bivalve populations of the northern sector of Monterey Bay.

At the present, there is little actual quantitative baseline data of Monterey Bay available to the marine scientist. This data is essential if biologists are to be able to monitor any changes within Monterey Bay whether they are due to natural causes or to pollution. It is the purpose of the Moss Landing Marine Laboratories Sea Grant and Association of Monterey Bay Area Governments (AMBAG) grants to obtain this baseline data on the physical, chemical, geological and biological aspects of the Monterey Bay. This paper deals with only a small portion of the biological data obtained.

TABLE 1

BENTHIC STATION LIST

STATION NUMBER	LATITUDE N	LONGITUDE W
1105	36° 51.0'	121° 49.8'
1107	36° 56.1'	122° 06.3'
1152	36° 54.8'	122° 01.0'
1153	36° 56.7'	121° 59.2'
1154	36° 55.5'	121° 52.6'
1156	36° 53.0'	121° 55.0'
1158	36° 55.1'	121° 56.7'
1159	36° 57.1'	121° 56.2'
1175	36° 50.2'	121° 50.2'
1176	36° 52.3'	121° 59.8'
1177	36° 53.6'	121° 57.5'

METHODS AND MATERIALS

A. Sampling

Twelve sampling stations were established in the northern sector of Monterey Bay (Figure 1, Table 1). Sampling of these stations took place on 20 August with five stations sampled, 21 August with four stations sampled and 13 October with three stations sampled. On the first two sampling dates, 20 and 21 August, eight replicates were taken. For the 13 October sampling the number of replicates was reduced to six due to financial and time limitations. Oliver (pers. comm.) has determined that at his Monterey Bay stations at 18 meters depth, six replicates are adequate to sample the majority of polycheate species present. The species to area curves for the bivalve species at the Sea Grant-AMBAG stations indicate that six replicates are adequate to sample the majority of the bivalve species present.

All sampling was done using a Smith-McIntyre grab (McIntyre, 1959) which samples an area of $.1 m^2$ to a depth of approximately 10 cm depending on substrate type.

B. Sorting

Sieving was done aboard the R.V. Amigo using a 1 mm Nytex screen with a .5 mm Nytex back-up screen. The remaining residue was preserved with 10% buffered formalin and taken back to the Moss Landing Marine Laboratories for sorting. The samples were rough sorted to six major groups (Polycheata, Bivalvia, other Mollusca, Crustacea, Echinodermata, and Miscellaneous phyla) and set aside to be identified by a qualified

graduate student.

C. Analysis of the Bivalvia Group

The bivalves were identified to their lowest possible taxa. The Shannon-Wiener Diversity Index, $H=-p_i Logp_i$, (Shannon and Weaver, 1949; Pielou, 1969) was then calculated for each sample. The diversity index values were then compared using the Kruskal-Wallace 1-way Analysis of Variance with the significance value adjusted for multiple testing (Fager, pers. comm.) to test the null hypothesis that there is a difference in the mean diversities among the stations within depths and among depths (0-25 M, 26-50 M and 51-75 M). Determination of recurrent groups was conducted using Fager's analysis of recurrent groups (1957, 1963, 1969). The bivalve population's patterns of distribution were analyzed using the variance to mean ratio method as described by Cox (1967).

TABLE 2

THE NAME, NUMBER FOUND AND THE RELATIVE ABUNDANCE OF EACH SPECIES TAKEN AT THE ELEVEN SEA GRANT-AMBAG STATIONS IN THE NORTHERN SECTOR OF MONTEREY BAY

Species	Number	Relative Abundance (%)
Astarte sp	110	2.74
Cardium quatrogenarium	35	.27
Compsomyax subdiaphana	18	.45
Cooperella subdiaphana	14	.35
Cuspidaria apodema	1	.02
Entodesma saxicola	7	.12
Lyonsia californica	8	.20
Macoma nasuata	123	3.06
Macoma yoldiformis	366	9.12
Mactra californica	245	6.10
Modiolus rectus	1	.02
Mya arenaria	1	.02
Mysella aleutica	198	4.93
Nemocardium centifilosum	334	8.32
Nucula tenuis	7	.17
Nuculana taphrina	434	10.81
Nuculana sp.	374	9.32
Pandora bilirata	46	1.15
Pandora punctata	1	.02
Pecten diegensis	1	.02
Pecten latiauratus	1	.02
Periploma discuss	65	1.62
Platyodon cancellatus	17	.42
Protothaca staminea	125	3.11
Saxidomus nuttalli	8	.20
Siliqua patula	332	8.27
Solamen columbianum	7	.17
Solen sicarius	33	.82
Tellina meropsis	2	.05
Tellina modesta	981	24.43
Tellina nuculoides	77	1.92
Unknown #3	18	.45
Vesicomya sp.	24	.60
Yoldia ensifera	1	.02

TABLE 3

RESULTS OF RECURRENT GROUP ANALYSIS

Group I

Mysella aleutica
Macoma yoldiformis
Nuculana taphrina
Siliqua patula
Tellina modesta

Group II

Cooperella subdiaphana
Macoma nasuata
Modiolus rectus
Platodon cancellatus
Protothaca staminea

Group III

Cardium quatrogenarium
Lyonsia californica
Mactra californica
Nemocardium centifilosum
Pandora bilirata

Group IV

Compsomyax subdiaphana
Nucula tenuis
Periploma discuss
Solen sicarius

RESULTS

Only eleven of the twelve stations sampled were used in this analysis. Station 1155 was discarded because the research vessel drifted approximately one nautical mile while on station. A total of thirty-four species of bivalves were taken at the eleven stations sampled. Of these thirty-four species, seven had a relative abundance greater than or equal to five percent and twenty had a relative abundance less than or equal to one percent (Table 2). Nineteen of these thirty-four species were able to be arranged into four groups (Table 3). The remaining fifteen species had affinities for some but not all of the members of one or the other groups and therefore did not fulfill Fager's second rule (Fager, 1957). The four groups were able to be placed in different depth ranges: 1) Group I, 0-25 M, 25-50 M and 51-75 M; 2) Group II, 0-25 M and 26-50 M; 3) Group III, 0-25 M; and 4) Group IV, 26-50 M and 51-75 M.

The Kruskal-Wallace 1-way analysis of variance tests conducted on the sample species diversity values rejected the null hypothesis and indicated that there was a high degree of difference among stations but not among depths. A number of Wilcox two sample one-tailed tests (Sokal and Rohlf, 1969) with their significance value adjusted for multiple tests were conducted to compare the means of the stations for each depth range. These tests revealed that there was no significant difference among the stations in the three depth ranges.

The variance to mean ratios used to determine the type of distribution within stations ranged from 2.14 to 26.03. All the variance

to mean ratios for each station were significantly different from one at the .05 level, indicating an aggregated or clumped population at each station (Cox, 1967).

CONCLUSIONS

If we accept Shelford's definition of a community as an "assemblage with unity of taxonomic composition and a relatively uniform appearance" (Odum, 1959, p. 246) then the analysis of recurrent groups indicates the existence of bivalve communities within the northern sector of Monterey Bay. This analysis also indicates that these communities are limited in their habitat selection by depth or some parameter that is correlated with depth.

The analysis of variance indicates that the diversity of the bivalve populations does not significantly differ with depth. However, it does indicate that there is a significant variance component among the stations. There are three possibilities as to the reason for the variance component: 1) enrichment of a few stations by sewage outfalls; 2) clumped populations; or 3) too small or too large a sample size.

If there had been enrichment of a station by a sewage outfall it would be expected that that station's mean diversity would be different from the mean diversities of the other stations. The Wilcox two-sample tests revealed that there is no significant difference among the stations with a given depth range. Therefore, enrichment is not occurring at the stations sampled or if it is occurring, it is affecting all the stations sampled approximately equally.

The variance to mean ratios reveal that the populations at the sample stations are clumped. This probably can be expanded to suggest that the bivalve populations of the northern sector of Monterey Bay exhibit a clumped population. Odum (1959) suggests that it is generally the rule and seldom the exception that most populations show an aggregated or clumped distribution. However, the test used to determine the type of distribution of the bivalve populations has the disadvantage that sample size may influence the results.

To determine if the sample sizes were too small, they were lumped together within each station to give four samples per station and then lumped again to give two samples per station. This experiment indicated that the samples were not too small but either of adequate size or too large. Therefore, it is suggested that the significant difference between stations within each depth range is due to the clumped populations found at the sample stations.

POSSIBLE SOURCES OF ERROR

The identifications were made using five keys: 1) Keen, 1958; 2) Keen, 1963; 3) McLean, 1969; 4) Morris, 1966; and 5) Soot-ryen, 1955. In addition, Smith and Gordon's 1948 paper on the marine mollusks of Monterey Bay was used as a second check to see if the species I found had ever been found before. I would consider the majority of my identifications reliable. However, I did experience difficulty differentiating between Macoma nasuata and M. secta and between the Yoldia and Nuculana genera. None of my identifications have been checked by experts in the field of bivalve identification. Therefore, the identifications are subject to change.

Even though the names may change the number of species found will probably remain the same plus or minus one or two. The species diversity values also should not change drastically. Therefore, all the information gleaned from the species diversity values is most likely correct.

The analysis of recurrent groups presented a number of problems. The original equation to determine the index of affinity of two species used by Fager (1957) has been changed but by whom I was unable to determine. The revised equation is used by Fager and McGowan (1963) and Fager (1969). However, the equation as written in these two papers is, to me, unworkable. With that equation the index of affinity is always a negative number. I therefore changed the equation so that it agreed with other authors' equations for indexes of similarity or affinity to $J/(N_A N_B)^{\frac{1}{2}} - \frac{1}{2}(N_B)^{\frac{1}{2}}$. The results of this new equation agreed with a table of the minimum values of J which are significant at the .05 level that Fager presented in his original paper (1957).

Fager made two limitations in the original description of the method to calculate recurrent groups: 1) if the ratio of N_B, the number of occurrences of species A, is greater than two, the index will not show a significant affinity; and 2) if the number of occurrences of species A is less than five the index will not show a significant affinity. I did not abide by these limitations. As a result only one of the four groups I obtained, Group I, can be obtained using Fager's original method. This group, Group I, is the only group that I find complete throughout the stations. The other groups have from one to three members missing where the majority of the other members

occur. Therefore, I would not be surprised if Groups II, III and IV were drastically changed or even omitted if and when my data is analyzed using Fager's computer program.

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APPENDIX A

LIST OF SPECIES FOUND PER STATION WITH THE NUMBERS OF INDIVIDUALS FOUND IN EACH REPLICATE

Station 1154

Species	Replicates							
	1	2	3	4	5	6	7	8
Clinocardium nuttalli		1		2	1	1		1
Macoma nasuata	2		2	3	4	3	4	2
Macoma yoldiformis	6		1	1	5	2	10	25
Mactra californica	1	9	2	8	2	15	10	24
Mysella aleutica						1		
Nemocardium centifilosum	9	32	24	54	14	61	68	49
Nuculana taphrina	3	2	1	3		6	1	9
Nuculana sp.	43	65	28	47	20	66	54	51
Pandora bilirata	2				1			
Panopea generosa				1				
Protothaca staminea		1		1		2	4	2
Siliqua patula	32	28	14	50	23	46	29	51
Tellina modesta	47	75	38	53	27	47	36	97

Sample depth: 13 meters

Date of sample: 20 August 1971

Station 1153

Species	Replicates							
	1	2	3	4	5	6	7	8
Cardium quatrogenarium				1	5			
Cooperella subdiaphana	1		2					
Lyonsia californica				1	1			
Macoma nasuata			1		2			
Macoma yoldiformis	1	1	13	10	5	4		
Mysella aleutica				1				
Nemocardium centifilosum	1	7	2		1	1		
Nuculana taphrina	13	6	48	26	25	27		
Pandora bilirata	4		3		14	6		
Pecten diegensis			1					
Protothaca staminea	6	3	18	2	7	6		
Siliqua patula	1					1		
Tellina modesta	15	13	38	36	17	21		

Sample depth: 14 meters

Date of Sample: 13 October 1971

Station 1159

Species	Replicates							
	1	2	3	4	5	6	7	8
Cardium quatrogenarium	2	5	4	5	5	1	2	3
Cooperella subdiaphana						1		
Entodesma saxicola				2				
Lyonsia californica				3	2		1	
Macoma yoldiformis	2	8	9	9	11	35	8	7
Mactra californica	1				1			
Modiolus rectus			1					
Mya arenaria							1	
Mysella aleutica		1		3	3	4	4	4
Nuculana taphrina	3	5	3	2	8		1	
Pandora bilirata			1		2			
Platyodon cancellatus			1		2			
Protothaca staminea	5	3	2	1	3	1	3	5
Saxidomus nuttalli		1		2		1		
Siliqua patula		1		6	4	3	1	1
Tellina modesta	9	40	19	38	28	19	9	21

Sample depth: 16.5 meters

Date of Sample: 20 August 1971

Station 1156

Species	Replicates							
	1	2	3	4	5	6	7	8
Astarte sp.	2			2	4	3	2	
Compsomyax subdiaphana	3	1		2	1	1	1	
Macoma nasuata	1	1			1		1	
Macoma yoldiformis	2	1	4	4	5	5	6	8
Entodesma saxicola			1					
Mysella aleutica	5	2	2	2	4	4	9	11
Nuculana taphrina	2		2	6	2		7	1
Platyodon cancellatus				1				
Siliqua patula				1				
Solamen columbianum						1		
Solen sicarius	1		1		4			1
Tellina modesta				1	1	2	2	1

Sample depth: 38 meters

Date of Sample: 21 August 1971

Station 1176

Species	Replicates							
	1	2	3	4	5	6	7	8
Astarte sp.	2	5	2	4	3	9		
Cooperella subdiaphana				1				
Cuspidaria apodema						1		
Macoma nasuata		1						
Macoma yoldiformis	6	2	3	1		2		
Mysella aleutica			1	7		4		
Nemocardium centifilosum				2				
Nucula tenuis	1			1		2		
Pandora bilirata						3		
Periploma discuss	11	11	13	8	4	9		
Solamen columbianum	2		1	1		2		
Unknown #4		2				2		
Vesicomya sp.	5	5	1	3	3	6		

Sample depth: 62 meters

Date of Sample: 13 October 1971

Station 1177

Species	Replicates							
	1	2	3	4	5	6	7	8
Astarte sp.	1	1	3	1	5	3	1	1
Compsomyax subdiaphana		1						
Cooperella subdiaphana					1		1	1
Entodesma saxicola					1			1
Macoma yoldiformis		5	5	2	2	2	2	2
Mysella aleutica	2			1	2			1
Nemocardium centifilosum			1					
Nuculana taphrina	1		10	4	2	2	4	
Pecten latiauratus				1				
Siliqua patula							1	
Tellina modesta					1			

Sample depth: 35 meters

Date of Sample: 21 August 1971

Station 1107

Species	Replicates							
	1	2	3	4	5	6	7	8
Astarte sp.	4	6	4	2	3	2		
Compsomyax subdiaphana	2	1		2	2	1		
Cooperella subdiaphana	1							
Entodesma saxicola			1					
Macoma yoldiformis	4	4	6	2	3	12		
Mysella aleutica	4	8	6	3	4	4		
Nucula tenuis			1	1				
Nuculana taphrina	3	2	2	1		1		
Periploma discuss	1	1	2	2	1	1		
Platyodon cancellatus			2	1				
Solen sicarius	2	2	1	1		3		
Tellina modesta		2						
Unknown #4	1	2	9			3		
Yolida ensifera						1		

Sample depth: 48 meters

Date of Sample: 13 October 1971

Station 1152

Species	Replicates							
	1	2	3	4	5	6	7	8
Astarte sp.	2	8	6	2	1	3	2	3
Cooperella subdiaphana	1			1			1	
Macoma yoldiformis	1	2	1	1	6	4	1	2
Mysella aleutica	3	2	5	19	3	4	2	5
Nuculana taphrina	1	5		3	5		2	
Periploma discuss			1					
Protothaca staminea	1							5
Tellina modesta	1							
Tellina sp.			1					
Saxidomus nuttalli	1					1	1	

Sample depth: 37 meters

Date of Sample: 20 August 1971

Station 1175

Species	Replicates							
	1	2	3	4	5	6	7	8
Astarte sp.					3			
Macoma nasuata			1		2	1		
Macoma yoldiformis	1	2						
Mactra californica			1		1			
Mysella aleutica			1	1		1		
Nucula tenuis	1							
Platyodon cancellatus						3		
Protothaca staminea		1						
Siliqua patula			1		1	3		1
Solen sicarius	1				1			1
Tallina mieropsis		2						
Vesicomya sp.						1		

Sample depth: 38 meters

Date of Sample: 21 August 1971

Station 1158

Species	Replicates							
	1	2	3	4	5	6	7	8
Astarte sp.	1		1		1		1	
Cooperella subdiaphana	1					1		
Macoma nasuata	5	2	1					1
Macoma yoldiformis	5	1	10	5	10	10	4	8
Mysella aleutica	5		2	1	1	2	2	1
Nuculana taphrina	7	3	7	3	5	2	1	6
Protothaca staminea				1				
Saxidomus nuttalli			2	1		1		
Siliqua patula	3		2	1	2	1	1	
Solen sicarius						1	1	3
Tellina modesta			1				1	1

Sample depth: 26 meters

Date of Sample: 20 August 1971

Station 1105

Species	Replicates							
	1	2	3	4	5	6	7	8
Astarte sp.								1
Cardium quatrogenarium	1	1	2		1		1	
Cooperella subdiaphana				1	1			
Entedesma saxicola						1		
Macoma nasuata	2	3		3			1	1
Macoma yoldiformis	1	1	5	2	2	4	1	3
Mactra californica	25	21	8	16	26	24	27	33
Mysella aleutica	1	4	2	6	8	1	6	4
Nuculana taphrina	18	15	11	16	19	14	21	26
Pandora bilirata	1		2	1	2	1	3	
Protothaca staminea	9	3	3	9	5	3	6	6
Platyodon cancellatus	4		1		1	1	2	
Siliqua patula				7	4	2	5	5
Solen sicarius		1		1		4	1	1
Tellina modesta	14	26	11	29	20	29	41	52
Tellina nuculoides	4	9	5	1	15	13	14	16

Sample depth: 11 meters

Date of Sample: 21 August 1971

PROGRESS REPORT: THE PRODUCTIVITY OF THE HALOPHYTIC VEGETATION OF ELKHORN SLOUGH, MONTEREY COUNTY, CALIFORNIA.

Recently attention has been focused on the salt marshes of Moss Landing by various groups and organizations, each with its own particular use for these areas in mind. The Nature Conservancy has acquired land at the upper end of Elkhorn Slough as a nature preserve. The Moss Landing Harbor District wishes to expand the present harbor facilities. The State beaches and parks in the area will certainly be developed in the near future to provide increased recreational use of the area. Some further industrial development is expected to add to the present industrial makeup of the area which includes the P. G. & E. plant, Kaiser Refractories, the boating, fishing and canning industry, a growing shellfish industry and some tourist-oriented businesses. All these uses will certainly intensify man's effects on Elkhorn Slough.

In the past little concern was given to maintenance of the natural beauty and resources of this area. Various forms of degradation have been the result, illustrated by lowered water quality detrimental to public health, and reduction of the value of the Slough as a haven for migratory waterfowl. Some commendable progress has been made to correct this damage and it is hoped that careful planning in the future will provide maximum beneficial use of the area while positive steps are made to improve and develop its recreational, aesthetic and intrinsic value as a desirable component of the local environment.

A certain degree of knowledge about a particular ecosystem such as a salt marsh is required before beneficial planning can begin. Few studies have been made on the halophytic marsh vegetation of the west coast of California and still fewer have included Elkhorn Slough. A careful study of these types of vegetation, their growth rate and distribution can provide directly rewarding information as well as providing clues to other environmental conditions.

Salt marsh vegetation in the Moss Landing area of Monterey Bay provides resident and migratory waterfowl with food and suitable nesting areas. The vegetation stabilizes channels and removes sediment from the water. It is a source of primary productivity to the food web of the estuarine and near-shore marine environments.

COMPLETED WORK

Detailed maps were prepared of the estuaries from aerial photographs on a 1 inch to 200 foot scale. The area of the slough covered by vegetation can be measured from the photographs. Some areas of the slough were excluded from the study area due to man-caused influences, particularly dikes. The productivity products from these areas are not readily available to the marine waters and are atypical of the tidally influenced estuary. The remaining areas of estuarine vegetation were divided into a grid and random sampling stations were chosen. The total area of vegetation included in this study and covered by flooding tides has been determined to be 2,980,000 m^2 or nearly 800 acres. Knowledge of this total area will make possible an assessment of the total productivity potentials of the marsh vegetation in this estuary.

The standing crop of vegetation was sampled at 20 randomly chosen sites. The vegetation was clipped off a $\frac{1}{4}$ m^2 plot at each station and placed in plastic bags. The sample size and number of stations were chosen as the maximum quantity of material which could be processed. Samples have been collected bimonthly for 10 months. Other data which have been taken for each sample include elevation, percent cover, number of species present and relative abundance of each, numbers and types of insects and mollusks, weather conditions, sediment type, condition of the plants and other subjective information.

The biomass samples are returned immediately after collection to the laboratories where species of plants are separated and weighed. These are then dried for 48 hours at 150° C to remove the moisture and reweighed. This procedure provides wet and dry biomass data and also data on succulence or quantity of moisture retained by the vegetation. One use of this data will be as an indicator of vigor in the plants.

Sediment samples taken at each sampling station will be analyzed for particle size distribution and organic content. The root growth patterns of each species of halophytes is under study. The oxygen content and salinity of the soil water are also to be measured.

A study of the rate at which the halophytic vegetation is broken down in the field is near completion. Fiberglass screen bags containing known quantities of dried vegetation were placed in the marsh where bacteria and the elements could break down the vegetation. Each month the remaining material has been weighed and a subsample removed, dried and weighed to provide data on the rate of decomposition as indicated by weight loss.

PRELIMINARY RESULTS

In the marsh area which is actually covered by the tides at any time, five species of halophytic plants were encountered in the biomass samples. These are, in order of decreasing quantity: Salicornia pacifica, Jaumea carnosa, Distichlis spicata, Frankinia grandifolia and Triglochin concinna. The latter four species comprise less than 3% of the dry weight of the identifiable living plant biomass. The overwhelming quantity of plant material is Salicornia, commonly known as Pickleweed. As of this writing the Salicornia appears to be of only one species, S. pacifica. However, there appear to be two forms of S. pacifica which seem to be separated by area; more may be learned of this as analysis progresses.

Figure I shows the mean biomass change through the year. The data show a steady loss of material from June through April amounting to 69 grams per $\frac{1}{4}$ m^2, or in excess of 826,000 kilograms in the area under study. Some of this material remains in the marsh system and some is transported out on tidal cycles. Some of the deposition has been measured and the transport of macro-detritus will be measured in the future using screen traps.

The biomass data seem to show a reduction in vegetation per unit area as one moves toward the upper end of the slough. If tests show this to be a significant reduction it will be further investigated.

FUTURE WORK

The collection of biomass data will have been completed by August, 1972, and analysis will then be possible. Data on particle size distribution, salinity and aeration of the substrate will be completed and will be compared to biomass data for correlation and regression analysis. Data on rate of decomposition will be complete so that some idea of the rate at which this material enters the food web will be known.

A general picture of the types, habits and productivity of the marsh vegetation in Elkhorn Slough will be useful to other studies in progress in the area. An understanding of the vegetation present and the environmental parameters it represents must be pursued, with the hope that past degradation indicated by an apparently decreasing diversity and volume of vegetation can be reversed with careful planning.

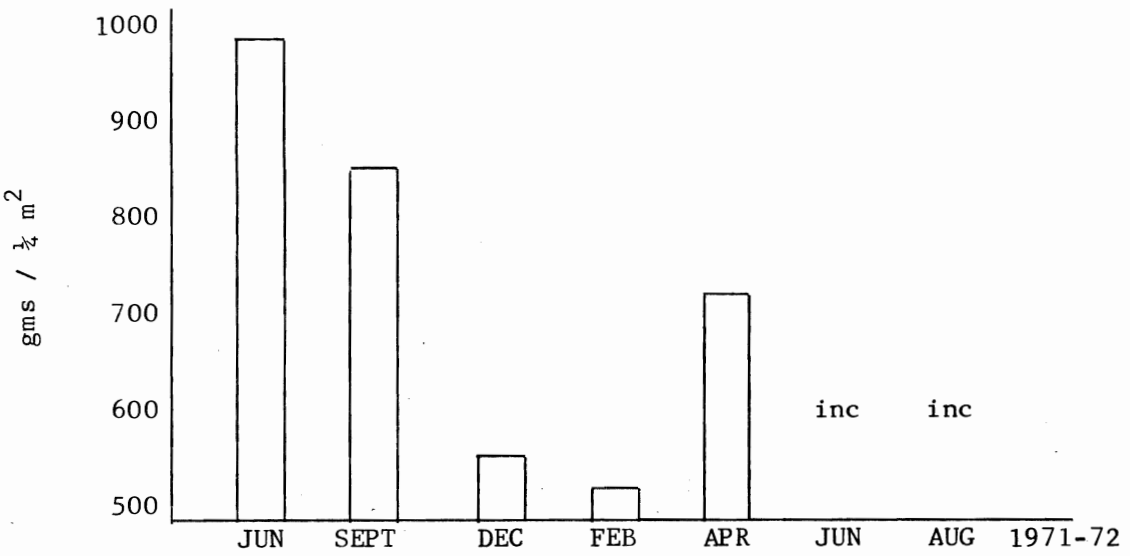

Fig. I. – Mean wet biomass change.

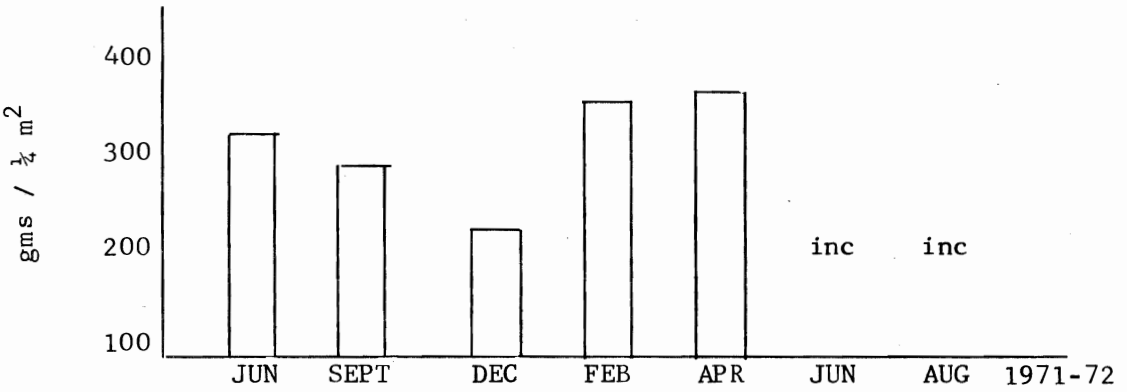

Fig. II. – Mean dry weight biomass change.

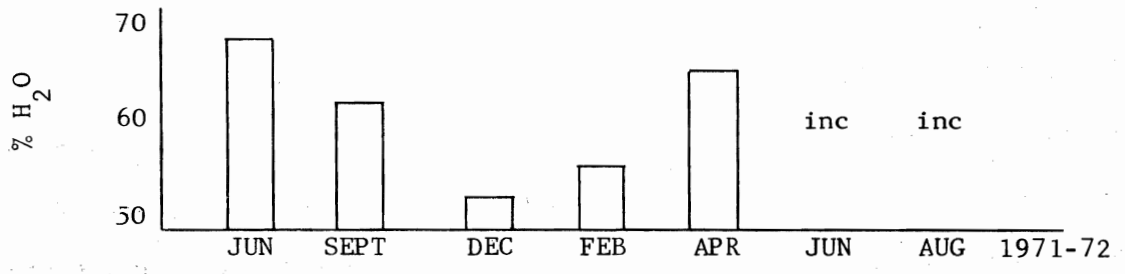

Fig. III. – Percentage of moisture in vegetation.

PLANKTON STUDIES

A plankton report is currently in preparation. This report will cover the results of the plankton program from February 1971 through August 1972. The report will consist of two parts: a technical section will present the data collected each month at all stations since the onset of the program; a discussion section will follow the technical section.

The first part or technical section will present station lists of chlorophyll *a* standing crop as a function of depth and will give the light penetration in the water column at each station (from either secchi values or percent transmission readings from a photometer). Productivity data from December 1971 through August 1972 will be included for six stations. Continuous profiles of surface fluorescence (related to phytoplankton biomass) in the study area will be presented for September 1971 through August 1972. Additional profiles of vertical fluorescence will be prepared at a number of stations from January through August 1972. Species lists of net phytoplankton from three stations will be presented for each month from September 1971 through August 1972. Zooplankton biomass (displacement volume) will be given at each station from September 1971 through August 1972.

The second part will include an interpretation of the data. The discussion will include a section on the seasonal trends in phytoplankton biomass and productivity and a section on the seasonal changes in species composition of the net phytoplankton. The phytoplankton biomass and production rates in northern, central and southern sectors

will be contrasted and the difference between biomass and productivity in inner and outer sectors of Monterey Bay noted. Correlations between phytoplankton productivity and nutrient concentrations will be examined. Additional factors that may affect the quantity and species composition of phytoplankton in the bay will be discussed.

The report will be published in October or November, 1972.